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Age and growth determination of the golden grey mullet, *Liza aurata* (Risso, 1810) from the Adriatic Sea by using scale readings and length frequency analysis

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The age and growth of golden grey mullet, Liza aurata *(Risso, 1810), were determined from specimens collected in the Mirna estuary (northern Adriatic Sea) during December of 2001, 2002 and 2003. The age composition was established using scale readings and Bhattacharya's method. Nine age classes ranging from 3.2 to 13.2 years (except 10.2 and 11.2) were defined by scale readings but only seven (age 3.2: 23.29 cm, age 4.2: 26.75 cm, age 5.2: 29.05 cm, age 6.2: 31.18 cm, age 7.2: 32.71 cm, age 8.2: 34.42 cm and age 9.2: 35.50 cm) were obtained by Bhattacharya's method. Total length ranged between 21.7 and 40.4 cm. Mean length and weight at age data, as derived using scale readings, were used to estimate the growth parameters of the von Bertalanffy equation:* $L\infty=40.0$, $K=0.214$, $t_o=-1.150$; $W\infty=606g$, $K=0.162$ *and* $t_o=-1.962$. *The length-weight relationship indicated positive allometric growth (b=3.069).*

Key words: Golden grey mullet, age determination methods, growth, Adriatic Sea

INTRODUCTION

The golden grey mullet, *Liza aurata*, is a pelagic coastal species which usually lives in inshore waters, entering lagoons and estuaries. It rarely enters freshwater and prefers a muddy bottom (JARDAS, 1996). Golden grey mullet occurs along the eastern Atlantic, from Cape Verde Islands and Senegal northward to the British Isles and around the southern coasts of Norway and Sweden (BEN-TUVIA, 1986). This species is relatively common in the Adriatic Sea (JARDAS, 1996) and in the rest of the Mediterranean Sea (BINI, 1968). It is a target of a commercial fishery along the eastern Adriatic coast with an annual catch of less than 60 tons (JARDAS, 1996).

Despite intensive investigations of the biology and ecology of the golden grey mullet in the Adriatic Sea (MOROVIĆ, 1960; KATAVIĆ, 1980; VILANNI, 1987; MODRUŠAN *et al*., 1988; KRALJEVIĆ & JUG-DUJAKOVIĆ, 1988; JUG-DUJAKOVIĆ, 1988) and elsewhere in the Mediterranean Sea (BOGRAD, 1961; CHERVINSKI, 1976; ALBERTINI-BERHAUT, 1978; CAMBRONY, 1984; BRUSLE & CAMBRONY, 1992), information on age and growth of adult specimens in the natural environment is still rather limited (ANDALORO, 1983; ARRUDA, 1991; KRALJEVIĆ & DULČIĆ, 1996; MOURA & GORDO, 2000; HOTOS, 2003).

The present study deals with aspects of age and growth of golden grey mullet collected from the Mirna Estuary (northern Adriatic Sea). Its aim is to resolve the contradictions in age determination data obtained from scale readings and length frequency analyses (LFA; Battacharya's method). Only a few previous studies (MEES *et*

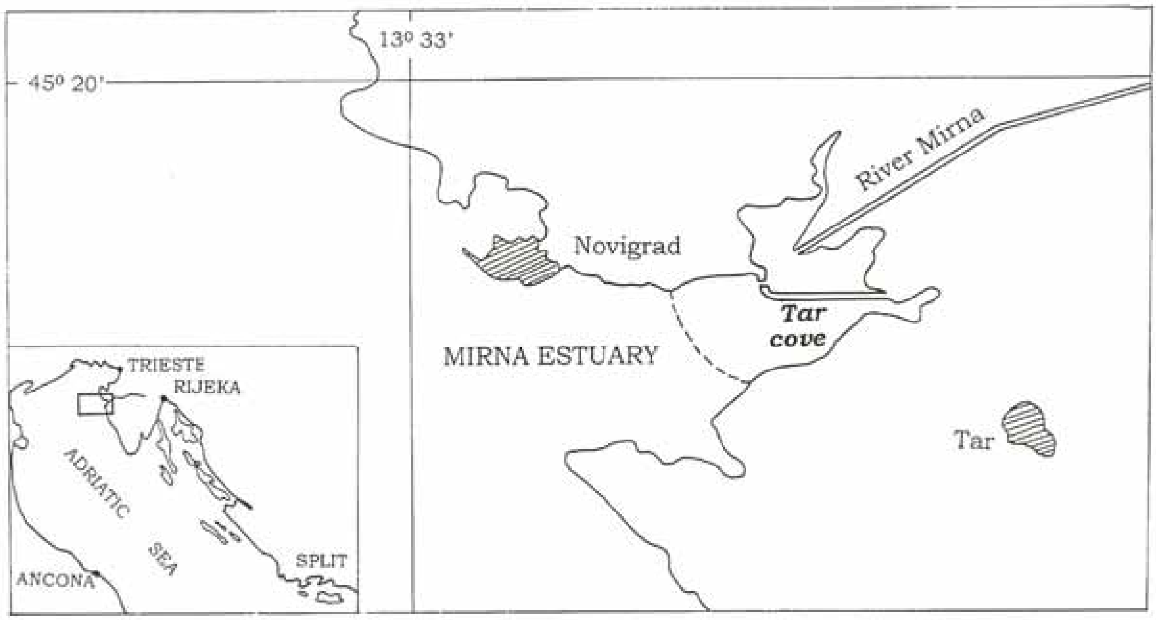

Fig. 1. Map showing the study area - Mirna estuary. Dashed line indicates the area where the net was set each year

al., 1994; KERSTAN, 1995; KRALJEVIĆ *et al*., 1995; MOURA & GORDO, 2000) attempted to resolve the contradiction between scale (otolith) ageing and length frequency analysis. Therefore, we compared these two methods on the same samples of golden grey mullet to note the advantages of each method usage.

MATERIALS AND METHODS

Golden grey mullets were collected as part of commercial landings in December 2001, 2002 and 2003 in the Mirna estuary, located on the western coast of the Istria peninsula (northern Adriatic). The Mirna Estuary (approximately 5.7 km^2) has been fished about once per year for more than 1000 years (BASIOLI, 1956). Fish were caught by long (1450 m in length) beach seine with bag (stretched mesh size 22 mm), and at depths from 15 to 30 m. This net was specially constructed for this area, and was set across the bay at 17 to 22 m depth (Fig. 1 dashed line). The net was then slowly towed by tractor for several days toward the inner end of the bay (Tar cove) until the fish were completely surrounded and were then caught at 3 to 5 m depth. To avoid damaging the fish intended for the market, only total length (TL) to the nearest 0.1 cm and weight (W) to the nearest 1.0 g were recorded. During three fishing seasons a total of approximately 12400 kg of *L. aurata* were caught as part of the professional fishermen's catch. Random samples of 446 individuals (from a total catch of 5832 kg achieved in 2001), 439 (from a total catch of 589 kg achieved in 2002) and 363 (from a total catch of 5968 kg achieved in 2003) fish were taken for age determination and growth analysis. The scales were collected from 1248 fish, but only 88.4% (1103) of them were clearly read by three readers. With respect to different fishing seasons, scale readings were analyzed on 87.9%, 92.3% and 84.3% of caught individuals.

Scale samples (15 to 20 scales each) were removed from the base of the pectoral fin and from the flank below the first dorsal fin from both sides of the body and were cleaned in 5% solution of sodium peroxide. Typically, a dark hyaline ring is laid down during the winter season. For our study, we assumed that this occurred between the second part of January and the second part of April when the temperature in the northern Adriatic Sea was the lowest in the whole water column (0-30 m) (DEGGOBIS, 1988). The age was determined by scale readings and by length frequency analyses (LFA) with the

Bhattacharya method (BATTACHARYA, 1967). The same individuals (1103) used for scale readings were also taken for the LFA.

Some authors (BĂNĂRESCU, 1964; CAMBRONY, 1984; BEN-TUVIA, 1986; KATSELIS *et al*., 1994) reported that the spawning season of the golden grey mullet ranges from August to November in the Mediterranean and the Black Seas, with the highest value of the gonadosomatic index in September in the Ionian Sea (HOTOS *et al*., 2000). Since there was no possibility of gonad examination (all fish were destined for the fish market), the period used to calculate the age of specimens collected in this study started at 0.2 years old (3.2, 4.2, 5.2, etc) from the birth date according to HOTOS *et al.* (2000).

The commonly used length-weight relationship $W=aL^b$ was applied (RICKER, 1975) for 1103 individuals, where W is the weight (g), L is the total length (cm), and a, b are constants. The condition factor (CF) was calculated as $CF=W100/L^3$.

The program Statistica, version 5.0 was used to estimate the growth parameters $L\infty$, K and t_0 in the ordinary von Bertalanffy equation: $L_t=L\infty\ (1-e^{-K(t-to)})$. The program uses a nonlinear least squares procedure, where the estimates $L_¥$, K and t_0 are determined by minimizing the sum of squared deviations between the observations and the estimated growth curve. The procedure is iterative and requires the entering of starting values for the iteration process. Weight growth was calculated using the following equation: $W_t=W\infty\ (1-e^{-K(t-to)})^3$.

The fish with readable scales (1103 of them) were divided into 39 length groups (0.5 cm intervals; from 21.5 to 40.5 cm). Modal Class Progression Analyses (MCPA) was used to separate length-frequency data into normal components (using the Bhattacharya's method) for detection and separation of cohorts. Mean total length at each age class was compared with the results of scale readings. Chi-square analysis was used to test the sample decomposition (SPARRE & VENEMA, 1992).

Overall growth performance was estimated by the indexF' (phi prime test) where F'=ln$K$+2ln$L\infty$ (MUNRO & PAULY, 1983; PAULY & MUNRO, 1984).

RESULTS

Length and weight frequency distribution

The length frequency distribution of 1103 fish is shown in Fig. 2. The total length of individuals ranged from 21.7 to 40.4 cm, while the weight ranged from 76 to 550 g (Table 1).

Age and growth

Nine age classes ranging from 3.2 to 13.2 years (except 10.2 and 11.2) were defined by scale readings (Table 2), but only seven separation of cohorts (age 3.2: 23.29 cm, age 4.2: 26.75 cm, age 5.2: 29.05 cm, age 6.2: 31.18 cm, age 7.2: 32.71 cm, age 8.2: 34.42 cm and age 9.2: 35.50 cm) were obtained by the length–frequency distribution with the Bhattacharya

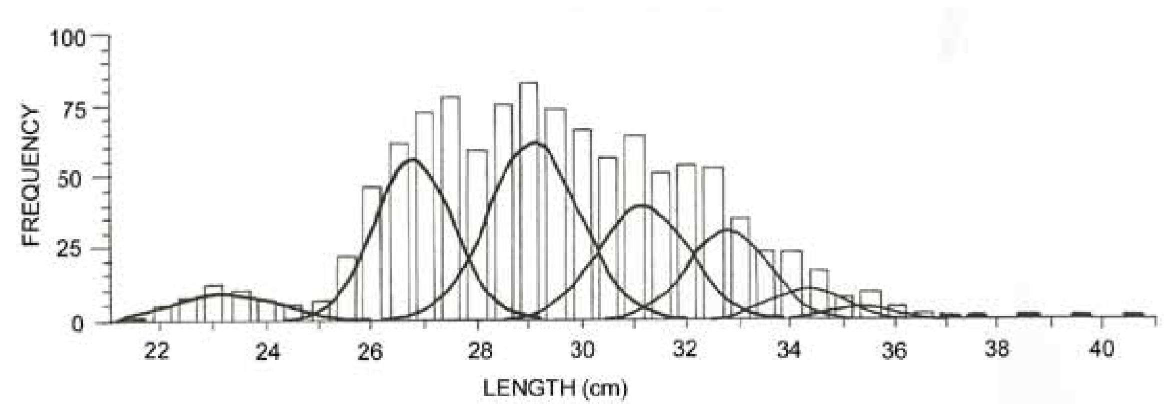

Fig. 2. Total length-frequency distribution (21.5-40.5cm) for the golden grey mullet, Liza aurata *caught in the Mirna estuary and separated into seven length groups (cohorts) by Bhattacharya's method*

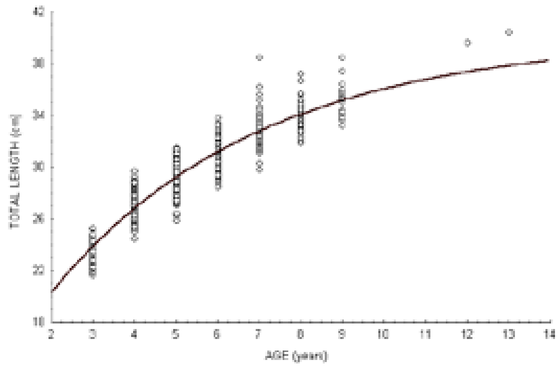

Fig. 3. Von Bertalanffy growth curve fitted by age-length of L. aurata

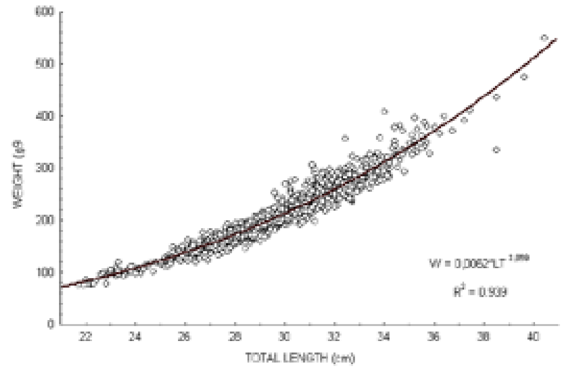

Fig. 4. Length-weight relationship of L. aurata *in the Mirna estuary*

method (Table 3; Fig. 2). The separation of the sampled population into seven cohorts by this method resulted in a good fit to the original fish distribution (N=1103) collected from the Mirna estuary (Chi-square value = 15.931; χ^2 0.05 (13) = 22.362). There were no significant differences (P>0.05; t-test of proportion; SOKAL & ROHLF, 1969) in the age-mean total length (Table 2) readings by scales and by cohorts-mean total lengths (Table 3) obtained by LFA. The mean total lengths of individuals assigned to each age group by scale reading were fitted to the von Bertalanffy growth model (Fig. 3). The growth parameters are presented in Table 4. The theoretical maximum of total length, 40.0 cm, is not unrealistic since the largest specimen sampled during the survey was 40.4 cm.

Length-weight relationship

The length-weight equation calculated was: W=0.0062 · $L^{3.069}$ (r^2=0.939). The slope of total length-weight relationship indicates positive allometric growth. The value of b=3.069 (SE=0.0213) is significantly different from 3.0

Table 1. Range, mean, standard error (S.E.), median and mode of total length (cm) and gross weight (g) of the golden grey mullet Liza aurata *from the Mirna estuary*

	Total length (cm)	Weight (g)
N	1103	1103
Range	21.7-40.4	76-550
Mean	29.37	205.6
S.E.	0.0852	1.895
Median	29.2	195
Mode	29.7	156

(t^=4.171; $t_{0.01,}\infty$=2.576) (Fig.4). The mean condition factor was estimated as 0.78 (SE=0.0017) with the minimum value of 0.63 and the maximum of 1.05.

DISCUSSION

Bhattacharya's method is useful for splitting a composite distribution into separate normal distributions when there are several fish cohorts (age groups; age-years classes) in the same sample (SPARRE & VENEMA, 1992), as were found in the present study. This method determined only seven cohorts while nine age classes were determined from scale readings. The two age classes not recorded by Bhattacharya's method were the oldest ones (12^+ and 13^+). This method was also applied by MOURA & GORDO (2000) on golden grey mullet resulting in a lack of age classes 5 and 6. The absence of certain age classes is probably due to the inability of Bhattacharya's method to recognize an age class when only a few individuals of the same age are present in a sample. For example, due to a small number of *Lithognathus mormyrus* individuals of age classes 2 and 8, KRALJEVIĆ *et al.* (1995) dealt with records of those cohorts by Bhattacharya's method. Usually the oldest found specimens (few individuals) that represent older age classes are omitted or added by this method to younger age classes, which was not a problem with a scale reading.

Sometimes, growth rings in scales were not clearly visible. In our study 88.4% were

Table 2. Age-length key for L. aurata *in the Mirna estuary based on scale reading*

Length intervals (cm)	Age (years)									Total (N)
	3.2	4.2	5.2	6.2	7.2	8.2	9.2	12.2	13.2	
21.3-21.7	1									1
21.8-22.2	5									5
22.3-22.7	8									8
22.8-23.2	12									12
23.3-23.7	11									11
23.8-24.2	7									7
24.3-24.7	4	1								5
24.8-25.2	2	5								7
25.3-25.7	1	21								22
25.8-26.2		46	1							47
26.3-26.7		60	2							62
26.8-27.2		69	4							73
27.3-27.7		70	8							78
27.8-28.2		35	24							59
28.3-28.7		18	56	2						76
28.8-29.2		6	72	5						83
29.3-29.7		2	63	9						74
29.8-30.2			45	21	1					67
30.3-30.7			22	34	1					57
30.8-31.2			10	53	2					65
31.3-31.7			2	41	8					51
31.8-32.2				29	23	2				54
32.3-32.7				13	36	4				53
32.8-33.2				5	23	6	1			35
33.3-33.7				2	10	10	1			23
33.8-34.2				1	4	16	2			23
34.3-34.7					2	11	3			16
34.8-35.2					1	3	4			8
35.3-35.7					1	2	7			10
35.8-36.2					1		3			4
36.3-36.7						1	1			2
36.8-37.2						1				1
37.3-37.7							1			1
37.8-38.2										
38.3-38.7							1			1
38.8-39.2										
39.3-39.7								1		1
39.8-40.2										
40.3-40.7									1	1
Total (N)	51	333	309	215	113	56	24	1	1	1103
%	4.62	30.19	28.01	19.49	10.24	5.08	2.18	0.09	0.09	100.0
Mean L_t cm	23.29	26.29	29.19	31.12	32.65	33.96	35.19	39.6	40.4	
±SD	0.85	0.88	0.92	0.94	0.93	1.03	1.18	-	-	
Mean W g	98.2	153.6	195.9	241.1	278.5	307.2	356.4	475	550	
±SD	12.2	17.8	25.2	27.7	29.9	31.8	38.1	-	-	

Table 3. Frequency distributions of L. aurata*, separated by Bhattacharya's method, from the Mirna estuary*

Cohorts	Age (year)	Mean total length (cm) ± SD	Population (N)	Separation index (SI)
1	3.2	23.29 ± 1.086	51.00	-
2	4.2	26.75 ± 0.737	280.50	3.827
3	5.2	29.05 ± 0.863	372.80	2.869
4	6.2	31.18 ± 0.832	222.70	2.479
5	7.2	32.71 ± 0.746	117.70	2.037
6	8.2	34.41 ± 0.665	39.83	2.102
7	9.2	35.50 ± 0.397	14.83	1.667

N=number of specimens in frequency sample

read successfully and 11.6% of scales were omitted. KERSTAN (1995) had similar results (10.1% omitted) for horse mackerel (*Trachurus trachurus capensis*) from the Agulhas Bank. Some Sparidae species (*Sarpa salpa*, *Lithognathus mormyrus*, *Sparus aurata*) from the eastern Adriatic Sea had less than 10% of scales unreadable (PALLAORO, DULČIĆ and KRALJEVIĆ, personal communication). Even better results were obtained in the study of the sagittal otoliths of *L. aurata*, where age could not be determined in only 0.5% of specimens (MOURA & GORDO, 2000). Same authors also noted that sagittal otoliths could not be determined in a very small percentage (1.7% and 0.9%) of the specimens of *L. ramada* and *Chelon labrosus*, respectively. According to ANDALORO (1983), scales are less legible than sagittae. Further, the preparation of scales, including taking, saving, cleaning, drying, reading and storing in paper envelopes is time consuming.

This is not the case with the Bhattacharya method since it requires less laboratory time. However, results of Bhattacharya's method may sometimes be dependent on the person performing the analysis (SPARRE & VENEMA, 1992), which isn't the case with the scale or otolith reading where three readers are involved. Further, it is also a great problem to take samples that would include all age (length) classes from relatively large fish catches. In large catches, only three or at most four age classes are dominant such as age classes 2^+-5^+ in this study. Reading the scales were found nine age classes while Bhattacharya's method estimated only seven, indicating that sampling was not random since it did not include all age classes present in a catch. The absence of small individuals was a direct consequence of fishing gear selectivity.

When the length groups were not completely included, the length frequency analysis by Bhattacharya's method cannot calculate all necessary cohorts. According to SPARRE & VENEMA (1992), one of the weaknesses of this method is in choosing how many points will each lie on a straight line (age classes) and which points can or can not be included in one or another line since they are based on subjective selection. In the first few regression analyses (age classes) these mistakes were not so common as later on, when the points were not distributed as clearly on the lines and each author had to make an

Table 4. Growth parameters of von Bertalanffy growth model of L. aurata *from the Mirna estuary*

Length (cm)			Weight (g)		
Parameters	Values	S.E.	Parameters	Values	S.E.
$L\infty$	39.98	0.2700	$W\infty$	605.7	0.2163
K	0.214	0.0033	K	0.162	0.0039
t_o	-1.150	0.0379	t_o	-1.962	0.0591
R^2	0.944		R^2	0.843	

Table 5. Parameters of the age, length range, length-weight relationship (b) and growth (L¥,K, t0) of L. aurata from the different study areas

Authors	Study area	N	Length range (cm)	Length	Age (years)	*b*	*L*∞ (cm)	*K*	t_0	Φ*
Albertini-Berhaut (1978)	Gulf of Marseilles	4800	1.5-18.5	SL	0^{+}-1^{+}	3.310	45.0	0.20	-0.49	6.004
Andaloro (1983)	Marsala Lagoon	423	-	-	1^{0}-6^{0}	-	24.3	0.63	-0.11	5.919
Modrušan et al. (1988)	Krka estuary –middle Adriatic	103	-	TL	2^{+}-3^{+} + 5^{+}	-	51.0	0.30	-0.40	6.660
Arruda et al. (1991)	Ria de Aveiro –Atlantic	3689	2.0-28.0	TL	0^{+}-4^{+}	2.929	68.5	0.11	-0.51	6.246
Kraljević and Dulčić (1996)	Mirna estuary -northern Adriatic	1073	21.0-41.8	TL	3^{+}-8^{+} + 11^{+}	3.161	39.8	0.21	-1.14	5.807
Moura and Gordo (2000)	Óbidos Lagoon -Atlantic	983	4.0-27.0	TL	0-6	3.031	31.3	0.24	-1.39	5.460
Hotos (2003)**	Lagoon of Messolonghi - W. Greece	1048	9-59.0	TL	0-8^{+}	-	-	-	-	-
Fehri-Bedui and Gharbi (2005)	Tunisian coasts	225	16.2-33.0	TL	0-5^{+}	3.009	39.7	0.16	-1.51	5.521
Hotos and Katselis (2011)	Messolonghi-Etoliko Lagoon	1065	9.7-59.0	TL	0-6	3.130	65.08	0.149	-1.15	5.81
	Gulf of Patraikos	81		TL	0-8^{+}	3.260				
Present study	Mirna estuary -northern Adriatic	1103	21.7-40.4	TL	3^{+}-9^{+} +12^{+}-13^{+}	3.069	40.0	0.21	-1.15	5.817

* Phi-prime test (this parameter was calculated by following other authors).

** von Bertalanffy equation was not used

TL, total length; SL, Standard length

independent decision of what would be calculated in each regression analysis. So, as MEES *et al.* (1994) stated, the Bhattacharya method is a powerful tool for identifying cohorts, but a careful examination of the population structure and length-frequency distributions of the different developmental stages is still necessary.

The golden grey mullet is a relatively long-lived species. The oldest specimen found in this study was 13-years old, while in the same study area KRALJEVIĆ & DULČIĆ (1996) found one 11-year old golden grey mullet. The largest fish caught had a total length of 40.4 cm and weight of 550 g. Similar measurements (TL=41.8cm; W=541g) were obtained by KRALJEVIĆ & DULČIĆ (1996). BINI (1968) reported 40 cm, GRUBIŠIĆ (1982) 45 cm and JARDAS (1996) 50 cm as a maximum total length for this species. In our computation, the asymptotic length of *L. aurata* was $L\infty$=40.0 cm and the value of *K* was 0.21. The same values were estimated by KRALJEVIĆ & DULČIĆ (1996), very similar values were obtained by ALBERTINI-BERHAUT (1978) from the Gulf Marseilles, while ARRUDA *et al.*, (1991) calculated a significantly larger $L\infty$=68.5 cm and smaller *K* =0.11 for *L. aurata* from Ria de Aveiro. MODRUŠAN *et al.* (1988), ANDALORO (1983) and HOTOS & KATSELIS (2011) found the longest values of asymptotic length (Table 5). The highest value of the growth rate *K*=0.63 was recorded by ANDALORO (1983) for the Marsala Lagoon, but even so, according to the *K* values obtained by other authors (Table 5), *L. aurata* is a slow-growing species. Differences in growth characteristics of specimens from salt lagoons to brackish estuary rivers can be attributed to the differences in food and environmental conditions (ELIZAROV, 1965; WEATHERLEY & GRILL, 1987). Interestingly, HOTOS & KATSELIS (2011) found recently that growth of *L. aurata* in the lagoon system and the neighboring seawater was not significantly different suggesting that the relatively high salinity level of the lagoon may deny a high trophic advantage for the fish and/or alternatively, by a scenario that is based on the seasonal migrations of species between sea and lagoon.

The growth of golden grey mullet in the Mirna estuary is positively allometric (*b*=3.069) which is the same as in the Golfo de Morbihan, though with higher *b* values (*b*=3.310 and 3.280; ALBERTINI-BERHAUT, 1978) and is in contrast to golden grey mullet from the Óbidos Lagoon (*b*=3.031; MOURA & GORDO, 2000) where the growth was isometric. ARRUDA *et al.* (1991) obtained negative allometric growth of the same species from the Ria de Aveiro (*b*=2.397) (Table 5) probably because younger age classes (0^+-2^+) dominated (94.9%) in their samples. Changes in fish shape, physiological changes, hydrological environmental conditions, different food availability during life and biological span, growth increment or break in growth can all affect the growth exponent (*b*) (FROST, 1945).

Overall growth performance F' computed from data presented by MODRUŠAN *et al.* (1988) and ARRUDA *et al.* (1991), of 6.660 and 6.246, respectively, is much higher, while that from MOURA & GORDO (2000) is much lower (5.460) than our estimates (5.817). That may be caused by differences in methodology of age readings, or by different environmental conditions. The F' values found by ALBERTINI-BERHAUT (1978), ANDALORO (1983) and KRALJEVIĆ & DULČIĆ (1996), (6.004, 5.919 and 5.807, respectively) are similar to our calculations. We assume our growth curve to be more reliable than these first three mentioned above, because different stocks were dealt with in the present study, even though they were the same species (Table 5).

In conclusion, in the Mugilidae family, scale reading is the most used method for age estimation especially due to the difficulty of otolith interpretation (MATIĆ-SKOKO *et al.,* 2011). On the other hand, the difficulty with recognition of the first annulus in older mugilids due to the opaque appearance of the scale's central part was previously reported (HOTOS, 2003). The application of LFA analysis relies on the availability and quality of data and could be proposed just for cases with a large sample represented with as much as possible a higher number of age classes, as it was the case in the present study. On the other hand, besides the fact that scale preparation and readings are time consuming and can be quite complex, skeletal structures have been historically more reliable and their analysis usually enables accurate determination of age classes. Regarding the studied species, future studies should attempt to estimate to what extent habitat conditions modify the growth pattern of *L. aurata*. It is also very important to incorporate juvenile growth into studies of population growth.

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Određivanje starosti i rasta cipla zlatara, *Liza aurata* (Risso, 1810) iz Jadrana primjenom metode očitavanja ljuski i analize dužinskih frekvencija

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SAŽETAK

Starost i rast cipla zlatara, *Liza aurata* (Risso, 1810) su određeni na jedinkama ulovljenima u estuariju rijeke Mirne (sjeverni Jadran) tijekom prosinca (2001, 2002, 2003 godina). Starost je određena očitavanjem ljusaka i Bhattacharya-vom metodom. Devet starosnih grupa u rasponu od 3,2 do 13,2 godina (osim 11,2 godine) je određeno čitanjem ljusaka, dok ih je samo sedam utvrđeno pomoću Bhattacharya-ve metode (3,2 god: 23,29 cm; 4,2 god: 26,75 cm; 5,2 god: 29,05 cm; 6,2 god: 31,18 cm; 7,2 god: 32,71 cm; 8,2 god: 34,42 cm; 9,2 god: 35,50 cm). Ukupna duljina cipla zlatca je bila u rasponu od 21,7 do 40,4 cm. Srednje dužine i mase pojedinih starosnih godišta očitanih na ljuskama su korištene za izračunavanje parametara von Bertalanffy-eve jednadžbe rasta: $L\infty=40,0$; $K=0,214$; $t_0=-1,150$; $W\infty=606$ g, $K=0,162$ and $t_0=-1,962$. Dužinsko-maseni odnos ove vrste je ukazao na pozitivan alomertijski rast ($b=3,069$).

Ključne riječi: Cipal zlatar, metode određivanja starosti, rast, Jadran